COMPUTATIONAL DYNAMICS ANALYSIS OF PROPELLER WITH AND WITHOUT FINS

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A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Mechanical Engineering with Automotive

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive

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STUDENT’S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

The project objectives are to ensure that the simulation results are valid by comparison with the Standard Series Data and compare the performance of propeller with and without fins, based on Computational Fluid Dynamics (CFD) analysis. The propeller is based on Wageningen B3.55 series and made from aluminium alloy. Theoretically the fins on the back side of propeller blade will increase the thrust produce by the propeller. The methodology of this project can be divide to three parts depends on the software used; PolyWorks, SolidWorks and CosmosFloWorks. The propeller is divided into two, with and without fins. A propeller with two fins in the format of PolyWorks file after the propeller had through 3D scan process is provided, thus further 3D modeling process using PolyWorks had to be made. Other than to process the propeller to desired shape, 3D modeling also used to smoothen the surface, eliminate any defects like hole and gaps on the surface of propeller. SolidWorks is important software in this project not only because it can read the IGES file format from PolyWorks, also CosmosFloWorks is the plug-in for SolidWorks. The function of CosmosFloWorks is to analyze the performance of propellers where the value of thrust and torque is taken. Thrust is the force produced at a given speed when propeller rotates and torque is the moment act on the propeller blades. The value of thrust and torque from Standard Series Data and analysis of propeller without fins is compared to make sure the data from analysis is valid. It is observed that the value of thrust from Standard Series Data is higher than the thrust value from propeller without fins around 4.3% and 2.6% for torque. The velocity of boat is set from 3 knots to 7 knots and the slippage is not considered in the analysis. The average increase of thrust by the propeller with fins compare to propeller without fins is around 9.1% and 4.4% for torque value.

ABSTRAK

Objektif projek ini adalah untuk memastikan keputusan daripada simulasi adalah sah melalui perbandingan antara 'Standard Series Data' dan prestasi kincir tanpa sirip berdasarkan kaedah analisis 'Computational Fluid Dynamics (CFD)'. Kincir yang digunakan dalam projek ini adalah berdasarkan siri model Wageningen B3.55 dan dibuat daripada aloi aluminium. Secara teori, sirip di permukaan belakang kincir akan menambahkan penghasilan jumlah daya oleh kincir. Metodologi projek ini dibahagikan kepada tiga bahagian bergantung kepada perisian yang digunakan; PolyWorks, SolidWorks and CosmosFloWorks. Kincir akan dibahagikan kepada dua iaitu dengan sirip dan tanpa sirip. Kincir dengan sirip diperolehi selepas daripada proses '3D scan', oleh itu proses permodelan 3D lebih lanjut harus dilakukan menggunakan PolyWorks. Selain daripada mengubah model ke bentuk yang dikehendaki, proses permodelan 3D juga digunakan untuk meratakan permukaan, menghapuskan sebarang kecacatan seperti lubang-lubang dan ruang-ruang pada permukaan kincir. SolidWorks adalah perisian yang penting bukan sahaja kerana ia dapat membaca file IGES daripada PolyWorks, malah CosmosFloWorks juga adalah plug-in kepada SolidWorks. Fungsi CosmosFloWorks adalah menganalisa prestasi kincir yang mana nilai daya tujahan dan tork yang dihasilkan dikira. Daya tujahan adalah daya yang dihasilkan oleh apabila kincir berputar pada kelajuan yang ditetapkan dan tork adalah daya putaran yang bertindak pada bilah kincir. Nilai daya tujahan dan tork daripada 'Standard Series Data' dibandingkan dengan nilai tersebut daripada analisis untuk memastikan keputusan daripada analisis boleh diterima. Dapat diperhatikan bahawa jumlah daya tujahan daripada 'Standard Series Data' adalah lebih tinggi daripada analisis sekitar sebanyak 4.3% dan 2.6% untuk tork. Halaju boat dalam projek adalah ditetapkan dari 3 knot ke 7 knot dan nilai gelinciran oleh kincir tidak diambil kira dalam analisis. Kincir dengan sirip meningkatkan daya tujahan sebanyak sekitar 9.1% dan tork sekitar 4.4% lebih tinggi daripada kincir tanpa sirip.

TABLE OF CONTENTS

		Page
SUPERVISOR'S DECLARATION		ii
STUDENT'S DECLARATION		iii
ACKNOWLEDGEMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF TABLES		xii
LIST OF FIGURES		xiii
CHAPTER 1	**INTRODUCTION**	
1.1	Introduction	1
1.3	Problem Statement	2
1.3	Objectives of the Project	2
1.4	Scope of Study	2
1.5	Overview if the Report	3

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction 4

2.2 Review of Propeller 5

2.2.1 Basic Nomenclatures of Propeller in Terms of Performance 5

2.2.2 Type of Propellers 8

2.2.3 Material of Propellers 9

2.3 Propeller Performance Characteristics 10

2.4 Definition of CFD Analysis and Software Used 12

2.4.1 Computational Fluid Dynamic (CFD) 12

2.4.2 PolyWorks 10.0 12

2.4.3 SolidWorks 2008 13

2.4.4 CosmosFloWorks 13

2.5 Inventions of Propeller With Fins 14

2.5.1 Introduction 14

2.5.2 The Dimensions of Fins 15

2.5.3 The Concept of Propeller with Fins 16

CHAPTER 3 METHODOLOGY

3.1 Introduction 18

3.2 3D Modeling 20

	3.2.1	Hole Filling	20
	3.2.2	Mesh Reconstruction	22
	3.2.3	Editing Model	22
	3.2.4	Creating Curve Network	24
	3.2.5	Creating NURBS Surfaces	26
3.3	Convert NURBS Surfaces to IGES File		27
3.4	Check for Geometry Error		28
3.5	Set the Boundary Conditions		29
	3.5.1	Analysis Type	30
	3.5.2	Rotation Type	30
	3.5.3	Fluids	30
	3.5.4	Creating Rotating Region	31
	3.5.5	Set the Computational Domain	33
	3.5.6	Set the Calculation Operations	34
	3.5.7	Set the Force Engineering Goal	34
3.6	Data Analysis		35

CHAPTER 4 RESULTS AND DISCUSSION

4.1	Introduction		36
4.2	Thrust and Torque Value from Standard Series Data		37
4.3	Thrust and Torque Value From Analysis		38
	4.3.1	Propeller Thrust	38
	4.3.2	Propeller Torque	41
4.4	Analysis on Flow Trajectories		44

CHAPTER 5 CONCLUSIONS

5.1	Introduction	46
5.2	Conclusions	46
5.3	Recommendations	47

LIST OF TABLES

Table No.	Title	Page
2.1	Type of propeller and their characteristic	8
2.2	Some analyze operation by CosmosFloWorks	13
4.1	Thrust and torque value from standard series data	37
4.2	Comparison of thrust from Standard Series Data against propeller without fins	38
4.3	Comparison of thrust value from propeller with and without fins	40
4.4	Comparison of torque from Standard Series Data against propeller without fins	41
4.5	Comparison of torque value from propeller with and without fins	43

LIST OF FIGURES

Figure No.	Title	Page
2.1	Diameter of propeller	5
2.2	An example of propeller with 21 inches pitch	6
2.3	Illustration of the slip on propeller	6
2.4	Illustration of the propeller dimensions	15
2.5	Illustrations of the pressure act on the surface of blade	16
3.1	Flowchart of the project	19
3.2	A sample of hole on the surface of propeller model	20
3.3	Dialog box for ‘Click & Fill Holes’ process	21
3.4	Surface of propeller after the hole was filled	21
3.5	Illustration of reconstruction operation	22
3.6	The area with red color was the selected area for this operation	23
3.7	Surface of propeller after the area of interest is deleted	23
3.8	Picture of particles on the surface of propeller from closer and different view	24
3.9	Dialog box for ‘Curve Network From Model’	25
3.10	Dialog box for ‘Fit Networks NURBS Surfaces’	26
3.11	Isometric, front and rear view of propeller with two fins	27
3.12	Isometric, front rear view of propeller without fins	27
3.13	Dialog box for ‘Import Diagnostics’	28
3.14	Dialog box for ‘General Settings’ in choosing the type of analysis	29

	and rotation	
3.15	Dialog box for 'General Settings' in choosing the project fluids	31
3.16	Simple cylinder shape of polygonal model as the rotating region	31
3.17	Arrangement of circle and propeller model from isometric view	32
3.18	Dialog box for 'Rotating Region'	32
3.19	Dialog box for 'Computational Domain'	33
3.20	Isometric view of computational domain area	33
3.21	Snapshot of 'Calculation Control Options' dialog box	34
3.22	The dialog box to start the analysis by CosmosFloWorks	35
4.1	Graph of thrust versus rotational speed	39
4.2	Graph of torque versus rotational speed	42
4.3	Flow trajectories at the back side of propeller with fins	45
4.4	Flow trajectories at the back side of propeller without fins	45

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Ship propulsion at the required sea speed occurs with the help of a propulsion device. The most common propulsor is the propeller, which converts engine torque to ship thrust, accelerating the fluid in which it works. The propeller plays an important role in the interaction between ship, engine and propulsor. Conventional propellers are mounted on a shaft and operate behind ship's hull.

Actually the propulsion of propeller is a very complex process that include knowledge in fluid dynamics, physics, metallurgy, naval architecture, mechanical and marine engineering. A lot of considerations has to be made and calculated using various theories such as momentum theory, blade element theory and thin aerofoil theory. However as the technology develop, new and easier analysis of performance of propeller can be made by using Computational Fluid Dynamics (CFD) analysis method.

1.2 PROBLEM STATEMENTS

Today, conventional marine propellers remain the standard propulsion mechanism for surface ships and underwater vehicles. The performance of the propeller is depend on various factors including their geometry and dimensions. Small changes of geometry would reasonably affecting the performance by decrease or increase the value of torque and thrust of propeller.

Existing propeller produce thrust and torque to enable the boat to move. However, the conventional design of propeller did not produce enough thrust. Therefore, new design needs to be produce such as the additional fins at the blades.

1.3 OBJECTIVES OF THE PROJECT

The main objective of this project is to conduct the computational fluid dynamic analysis of propeller. The overall objectives are:

i. To ensure that the simulation results is valid by comparison with the Standard Series Data.
ii. To compare and investigate the performance of propeller with and without fins.

1.4 SCOPE OF STUDY

This project concentrates on the performance of the propeller when attached with fins. The scopes of study are as follows:

(i) 3D modeling using PolyWorks
(ii) Computational fluid dynamics analysis using SolidWorks and CosmosFloWorks.

1.5 OVERVIEW OF THE REPORT

Chapter 1 gives the brief the content and background of the project. The problem statement, scope of study and objectives are also discussed in this chapter.

Chapter 2 discuss about the basic nomenclature of propeller in terms of performance, types, performance characteristics and failure of marine propellers. Also definition of Computational Fluid Dynamics (CFD) analysis and software used in this project elaborated in this chapter.

Chapter 3 presents the flowchart, 3D modeling process and analysis operation involve in this project.

Chapter 4 explaining the result obtains from chapter 3 and discussion. This is including data presentations using graph, flow trajectories and others.

Chapter 5 presents the conclusions of the project. Suggestions and recommendations for the future work are put forward in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of the marine propeller, definition of Computational Fluid Dynamics (CFD) analysis, performance characteristics of propeller, software involve in this project and the background of propeller with invention. The review is fairly detailed so that the present research effort can be properly modified to add to the present body of literature as well as to justify the scope and direction of present research effort.

2.2 REVIEW OF PROPELLER

2.2.1 Basic Nomenclatures of Propeller in Terms of Performance.

Diameter

Diameter is crucial geometric parameters in determining the amount of power that a propeller can absorb and deliver, thus determining the thrust available for propulsion. Usually the diameter is proportional to the efficiency of propeller, but in high speed vessels larger diameters equates high drag. For typical vessels a small increase in diameter translates into a dramatic increase in thrust and torque load on the engine shaft, thus the larger the diameter the slower the propeller will turn, limited by structural loading and engine rating.

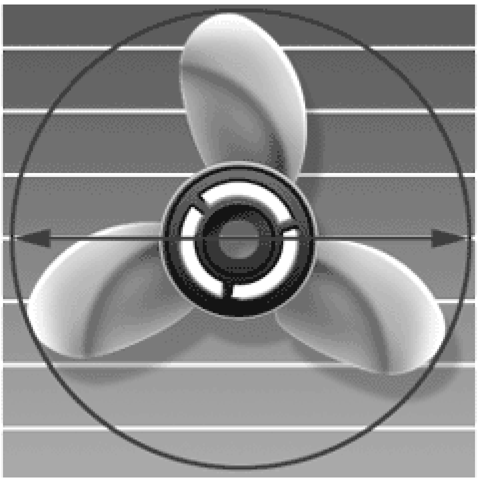

Figure 2.1: Diameter of propeller

Pitch

Pitch is the theoretical distance travel in one revolution of propeller. For example, the propeller move 10 inches in one revolution, thus the nominal pitch of the propeller is 10 inches. It is called nominal pitch because the actual pitch of propeller will be less than the nominal pitch. The difference between nominal and actual pitch is called slip.

Slip is the difference between actual and theoretical travel of the propeller blades through water. A properly matched propeller will actually move forward about 80 to 90 percent of the theoretical pitch. The ratio of pitch to diameter (P/D) is typically falls between 0.5 and 2.5 with an optimal value for most vessels closer to 0.8 to 1.8. Pitch effectively converts torque of the propeller shaft to thrust by deflecting or accelerating the water astern – simple Newton's Second Law.

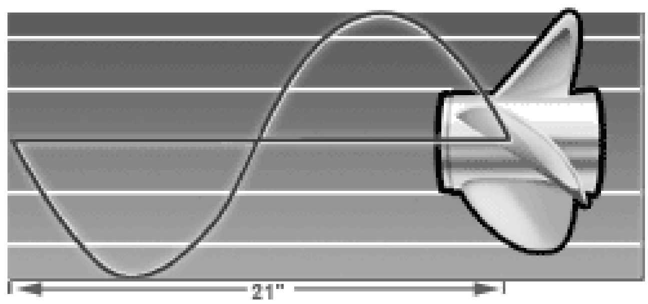

Figure 2.2: An example of propeller with 21 inches pitch

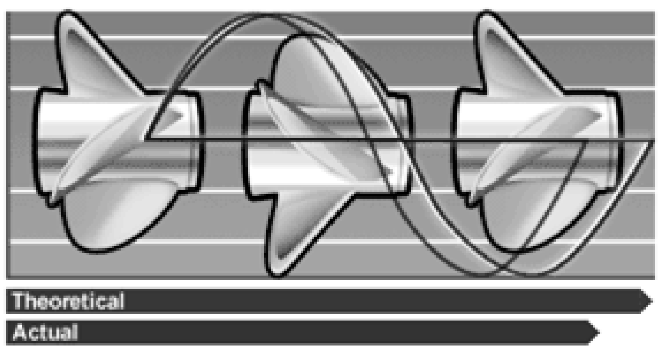

Figure 2.3: Illustration of the slip on propeller

Hub

Solid centre disk that mates with the propeller shaft and blades. Ideally the hub should be as small in diameter as possible to obtain maximum thrust, however there is a tradeoff between size and strength. Too small a hub ultimately will not be strong enough.

Blade

Blades are the twisted fins or foils that protrude from the propeller hub. The shape of the blades and the speed at which they are driven dictates the torque a given propeller can deliver. Blade root is where the blade attached to the hub, and blade tip is the outermost edge of blade at a point furthest from the propeller shaft.

High pressure side of blade is called blade face. This is the side that faces aft (backward) and pushes the vessels in forward motion. The back of the blade is the low pressure side or the suction face of the blade. This is the side that faces upstream or towards the front of the vessel.

Number of blades

The number of blades will critically dictate the performance of a propeller. Basically greater speed, horsepower and load requirements of vessel need propeller with more blades. In design consideration, the number of blades is primarily determined by the need to avoid harmful resonant frequencies of the ship structure and machinery. It also found that both propeller efficiency and optimum propeller diameter increase as blade number decrease.

With increased number of blades the surface area increases which reduces the slip in cruising speeds. Increased number of blades also gives a smoother behavior of the vessel with greater control in turns and in rough waters. Four and five blade propeller are also reducing vibrations and noise due to a better balance and are causing less wear on the transmission system. Adding blades however often decreases top speed with a couple of knots, but this is a trade-off in the propeller selection process. The propeller in this project has three blades.

2.2.2 Type of Propellers

The type of propeller and their characteristics are discussed in table below:

Table 2.1: Type of propeller and their characteristic

Propeller Type	**Characteristics**
Fixed pitch propellers	Ease of manufacturer Design for single condition Blade root dictates boss length No restriction on blade area or shape Rotational speed varies with power absorbed Relatively for small vessels
Controllable pitch propellers	Can accommodate multiple operating conditions Constant or variable shaft speed operation Increased mechanical complexity Larger hub size
Ducted propellers	Can accommodate fixed and controllable pitch propellers Enhanced thrust at low ship speed Duct form can be either accelerating or decelerating
Azimuthing units	Good directional control of thrust Increase mechanical complexity Can employ either ducted or non-ducted propellers of either fixed or controllable pitch type
Cycloidal propellers	Good directional of thrust Avoids need for rudder on vessel Increase mechanical complexity
Contra-rotating propellers	Enhanced propulsive efficiency in appropriate conditions Increased mechanical complexity

Source: Carlton, J. 2007. Marine Propellers and Propulsion Second Edition.

The propeller used in this project is type fixed-pitch propeller.

2.2.3 Material of Propellers

The materials from which propellers are made today can broadly be classed as members of the bronzes or stainless steels. The once popular of cast iron has now virtually disappeared, even for the production of spare propellers, in favor of materials with better mechanical and cavitation resistant properties. The propeller in this project is made from aluminium alloy.

The properties required in a propeller material will depend to a very large extent on the duty and service conditions of the vessel to which propeller are being fitted. However, the most desirable set of properties which it should posses as follows:

(i) High corrosion fatigue resistance in water
(ii) High resistance to cavitation erosion
(iii) Good resistance to general corrosion
(iv) High strength to weight ratio
(v) Good repair characteristics including weldability and freedom from subsequent cracking
(vi) Good casting characteristics

2.3 PROPELLER PERFORMANCE CHARACTERISTICS

The performance of propellers are mostly depends on the thrust produced. Thrust is a force that driven the propeller forward. Actually the details on how a propeller generates thrust are very complex. A lot of consideration must be made including the wake field, temperature, water density and others. However it still can be elaborated using simplified momentum theory.

Simple momentum theory state that the thrust of a propeller depends on the volume of fluid accelerated per time unit, fluid acceleration and density of medium. The formula based on momentum theory expressed by equation (2.1) below.

$$= \quad 4 \cdot \quad \cdot \quad + \frac{\Delta}{2} \cdot \quad \cdot \Delta \qquad (2.1)$$

Where:

T	Thrust
D	Diameter
V	Velocity of incoming flow
Δ	Additional velocity accelerated by propeller
ρ	Density of fluid (water: ρ = 1000kg/m^3)

Examining this quite simple formula reveals that the thrust, T increases when the diameter, D increases or when the density, ρ of the medium increases. The acceleration, Δv of a propeller depends on the velocity, v, thus it is generally not true that increasing the velocity increases the thrust. But it can be said, that increasing the additional velocity increases the thrust.

The performance characteristics of a marine propeller can be divided into two; open water and behind-hull properties. Open water characteristics relate to the description of the forces and moments acting on the propeller when operating in a uniform fluid stream. Behind-hull properties are performance of propeller in a mixed wake field behind a body, thus more complex and closer to actual performance. However we only discussing open water characteristics since these form basic performance parameter of propellers.

The forces and moments produced by the propeller are expressed in their most fundamental form in terms of a series of non-dimensional characteristics. The terms used to express general performance of propeller are as follows:

Thrust coefficient: = (2.2)

Torque coefficient: = (2.3)

Advance coefficient: $J = {}^{V_a}/_{nD}$ (2.4)

Where:

T	Thrust
Q	Torque
D	Diameter
ρ	Density of fluid
n	Rotational speed
V_a	Speed of advance